NOT FOR PUBLICATION UNTIL RELEASED
BY THE SUBCOMMITTEE ON STRATEGIC FORCES
COMMITTEE ON ARMED SERVICES
UNITED STATES HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE

PRESENTATION TO THE SUBCOMMITTEE ON STRATEGIC FORCES

COMMITTEE ON ARMED SERVICES

UNITED STATES HOUSE OF REPRESENTATIVES

SUBJECT: SUSTAINING GPS FOR NATIONAL SECURITY

STATEMENT OF: GENERAL WILLIAM L. SHELTON

COMMANDER, AIR FORCE SPACE COMMAND

September 15, 2011

NOT FOR PUBLICATION UNTIL RELEASED
BY THE SUBCOMMITTEE ON STRATEGIC FORCES
COMMITTEE ON ARMED SERVICES
UNITED STATES HOUSE OF REPRESENTATIVES

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
15 SEP 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Sustaining GPS for National Security	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Space Command,Los Angeles,CA,90245**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**12**	

Introduction

Mister Chairman, Representative Sanchez and distinguished members of the Subcommittee, it is my honor to appear before you as the Commander of Air Force Space Command (AFSPC).

As the Air Force lead for organizing, training and equipping space and cyber capabilities, an important part of my command's responsibilities is to develop, build, launch, operate and maintain the Global Positioning System (GPS) constellation of satellites. These actions culminate in our delivering extremely accurate positioning, navigation and timing (PNT) services for billions of users worldwide. Today, my testimony will center on the results of testing conducted thus far on the planned LightSquared terrestrial network in relation to GPS signals and services. I will also briefly comment on LightSquared-proposed modifications to their original deployment plan which was the basis for the initial testing. Thank you for the opportunity to testify on this important issue.

PNT services are crucial in defense, civil, and commercial activities. Although the GPS satellite constellation is procured and operated by the US Air Force, its utility is leveraged extensively by a broad user community, including civil, commercial, and military sectors. For our military, GPS has become an integrated part of US and coalition training and operations. GPS is used by all our Services, from boots-on-the-ground patrols, to precision-guided munitions, to synchronization and security of communications networks, to search and rescue operations, to humanitarian relief operations. As I stated to this Subcommittee in my March 2011 testimony, I believe AFSPC has an obligation to provide the best support possible to our brothers and sisters in harm's way. GPS helps fulfill that obligation by providing an essential capability that is a tremendous enabler and enhancer of joint, combined, and allied operations.

The innovative uses of GPS are also interwoven into a wide array of civil and commercial sector applications. Examples include the aviation community, where GPS is used by the Federal Aviation Administration (FAA) to help control our national airspace. GPS is used by the Department of Homeland Security for National border and maritime security. First responders, such as law enforcement, medical emergency and firefighting crews, depend on GPS for easy and accurate ground navigation allowing quick responses to time-urgent events. Activities such as mining, surveying, shipping, banking, and telecommunications rely on GPS's PNT services as well. As a Nation, we have invested roughly $34 billion to field and operate the GPS constellation. Clearly, it has become a global utility serving a worldwide user population.

As the Department of Defense's experts on GPS, AFSPC participated in recent testing to determine the effects, if any, of the originally planned LightSquared broadband service on the continued availability and reliability of GPS. These tests were conducted in the most realistic way possible with equipment and personnel provided by LightSquared. In summary, the test data collected by DoD, civil agencies, GPS industry partners, GPS receiver manufacturers, and GPS service providers all indicate the LightSquared terrestrial network operating in the originally proposed manner poses significant challenges for almost all GPS users. Below, I will briefly summarize the test activities that led to this conclusion.

GPS Considerations Regarding Proposed LightSquared Broadband Service

In January of this year, LightSquared (LSQ) was granted a conditional waiver. The waiver would permit LSQ to provide terrestrial-only service in two 10 MHz wide radio frequency bands adjacent to the GPS L1 signal once all interference concerns are resolved. This decision would fundamentally alter the use of the Mobile Satellite Service frequency band immediately adjacent

to GPS L1 by allowing a ground-based 4G broadband network to become the primary user—previously only transmissions of a similar strength to the GPS signal were allowed. The waiver included direction to LSQ to establish a working group with the GPS community to study potential interference to GPS, with a final report due no later than June 15, 2011. The report was to include the working group's analyses of the potential for overload interference to GPS devices from LSQ's terrestrial network, technical and operational steps to avoid such interference, and specific recommendations to mitigate potential interference to GPS. The LightSquared Working Group study report was filed on June 30, 2011. AFSPC had two representatives on that working group.

Parallel to, and independent of, the LightSquared Working Group study, the Executive Steering Group of the interagency National Executive Committee for Space-Based Positioning, Navigation, and Timing tasked the National Positioning, Navigation & Timing Engineering Forum (NPEF) to conduct an independent assessment of the LSQ planned deployment. The NPEF is co-chaired by the FAA's Ground Segment Lead for Global Navigation Satellite Systems and Space Based Augmentation Systems and the Chief Engineer, Air Force Space Command's Space and Missile Systems Center GPS Directorate. The NPEF testing was an interagency effort, with test participants including the US Naval Observatory, National Geospatial-Intelligence Agency, US Coast Guard, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration (NASA), the Department of Justice, and FAA.

Additionally, the NPEF test was open to state and commercial partners, which included the State of New Mexico Emergency Services, General Motors/On-Star, Chrysler, Ford, Trimble Navigation, Novatel, U-blox and John Deere. Each of these organizations' representatives was

responsible for their own equipment and the data they obtained. Of particular note, the NPEF test is the only test thus far involving military receivers.

NPEF Test and Results

Preliminary Interference Analysis

To provide a baseline for the NPEF Tests, in February 2011, one of our Federally Funded Research and Development Centers conducted interference analyses using signal characteristics and other data provided by LSQ. Based on the LSQ-provided deployment plan in urban areas, the typical user likely will be no more than 400 meters from a LSQ tower. The analysis showed that some GPS receivers could encounter signal reception interference at distances of several kilometers from a LSQ tower; therefore, the analysis concluded interference would be particularly acute in urban environments.

General Overview

The NPEF test was conducted in two phases during April 2011. It was facilitated throughout by the Air Force's professional GPS test squadron, the 746th Test Squadron at Holloman Air Force Base, New Mexico, and we owe them our thanks. As previously stated, LightSquared participated in the tests, providing and operating their own transmitters and antennas to simulate as closely as possible the LightSquared network signals that would be present under their originally proposed plan. The test was robust and comprehensive, involving over 100 receivers

from 24 different organizations, spanning the military, government, aviation, precision agriculture, automotive, and general use communities.

The first test phase involved anechoic chamber tests in a closed, controlled environment at White Sands Missile Range, New Mexico. The second phase, called "live sky" tests, used the same equipment and receivers, and was conducted in the open air environment at Holloman AFB, New Mexico. The test included 29 different types of military receivers, such as handheld models used by ground forces, aircraft units installed in F-15s and F-16s, weapons receivers used in GPS-guided munitions, and receivers used in our Remotely Piloted Aircraft.

The Coast Guard, NASA, FAA, and GPS industry organizations, such as Trimble, Novatel and John Deere, conducted their own independent testing during the DoD test event with 50 different types of receivers using the same test configuration.

The test results demonstrated empirically that the LightSquared signals interfere with all of the types of receivers in the test. The military results were compiled in a report that was submitted through the National Telecommunications and Information Administration (NTIA) to the FCC on July 6, 2011. The NPEF test results also are consistent with results obtained by commercial GPS industry organizations such as Trimble, Garmin and John Deere through their own independently conducted tests. I defer to these companies regarding their specific results.

Specific NPEF Test Results

For both the chamber and live sky phases, the NPEF test simulated all three phases of the originally announced LSQ deployment plan. Limited additional testing was accomplished on the 10 MHz single band in the portion of the spectrum farthest from the GPS L1 signal, the lower 10 MHz channel of the allocated bands.

Actual test results indicated significant degradation to every receiver-type tested. Most of the units tested completely lost their GPS service at some point. The specific military receiver test results are classified, but the results were consistent with the other receiver test results.

A. Aviation receivers operating as far as 7.5 miles from LightSquared transmitters completely lost GPS and were degraded out to distances of more than 16.5 miles. For two representative receivers tested by the FAA, results also showed GPS would be completely unusable for an aircraft 500 feet above the ground in an area spanning Stafford, Virginia through Washington and Baltimore, and out to Frederick, Maryland.

B. High precision GPS receivers such as those used for surveying and geological study requiring precise measurements were adversely affected out to 213 miles and totally lost GPS out to 4.8 miles.

C. Based on testing performed at the Jet Propulsion Laboratory, a class of receivers used in space to conduct certain types of atmospheric measurements would be unusable up to 12% of the time while in their typical orbits.

D. The State of New Mexico E-911 Program Director, who sent several GPS-equipped emergency and police vehicles to the test, stated in a letter to AFSPC that their equipment showed "the LightSquared network will cause interference to GPS signals and jeopardize 911 and public safety."

The NPEF testing also demonstrated a phenomenon known as "intermodulation products," essentially described as an echo effect resulting from the originally planned two channel operation of LSQ transmitters. This "echo" multiplies the impact of interference in GPS receivers and, to the best of our knowledge, cannot be suppressed by postulated LSQ transmit filters.

NPEF Test Limitations

In the interest of full disclosure, the NPEF test had several limitations due to time and resource constraints. These limitations included the following:

Not all GPS receivers/applications were tested. Examples include receivers dependent upon GPS for timing and cell phones with GPS applications. Some of these were tested by the LSQ Working Group.

As stated earlier, LSQ provided us with transmit equipment to conduct our testing. However, we were limited to a single LSQ transmit antenna. The aggregate effects of the nearly 40,000 antennas in LSQ's proposed network had to be modeled based on single transmitter test results. That modeling showed that the complete network of high-powered base stations envisioned by LightSquared would result in degradation or loss of GPS at distances out to dozens of miles and even extending out to operations in space.

LSQ network handsets (i.e., cell phones) are also radio transmitters and will operate in the frequency band just above the GPS L1 band. Although the handsets will transmit at lower powers than the tower transmitters, GPS users in close proximity (1 meter or less) to LSQ handsets theoretically could encounter interference in addition to the interference from tower transmitters. We are not aware if LSQ has built a prototype handset transmitter, so there are no test results to prove or disprove this concern.

LightSquared Working Group Test and Results

As stated earlier, the LightSquared Working Group also conducted tests. In general, those test results are consistent with the results obtained by the civil and commercial participants in the NPEF test.

As an adjunct to the report, LSQ submitted additional independent analysis and recommendations. One key point of divergence between the GPS community and LightSquared affecting the interpretation of test results is the definition of "harmful interference." The commonly accepted level of interference in applications such as this is, formally documented by the International Telecommunication Union (ITU), is defined as 1 decibel (dB). LightSquared proposes harmful interference be defined as 6 dB, and because decibels are a logarithmic function, this definitional change would represent a 300% increase in the allowable noise received by GPS users. Our analysis indicates that to overcome this level of interference would require GPS satellites to broadcast signals four times more powerful than current power levels to compensate for this difference. We believe such a change would more than double the cost of GPS satellites and take 15 years or more to fully implement.

Proposed Mitigations

In accordance with the NPEF test plan, possible mitigation measures were evaluated, but all were deemed impractical as they would require significant modification, redesign and/or replacement of existing GPS equipment, of which there are literally billions worldwide. For the military alone, there are significant costs involved in re-designing, manufacturing, testing, fielding and integrating new or modified GPS receivers in our military equipment and weapons systems. The same is likely true for other GPS-dependent entities worldwide.

Additionally, impacts to certain user groups might not be mitigated under any circumstances because the LSQ signal would create interference that would reduce the level of GPS service below minimum requirements. An example of this is John Deere's StarFire service, which provides augmented GPS signals for the high precision agriculture and construction industries, as well as Department of Defense use.

Since the testing, which was based on the originally submitted deployment plan, LightSquared proposed a temporary, modified deployment plan. Key features of that revised plan include:

A. Operate at lower power than their current FCC license allows.

B. Broadcasting in just the lower 10 MHz channel of the allocated frequencies.

We believe the signal strength proposed as "lower power" is actually the same as in the originally published LightSquared plan—and was the power level upon which the NPEF tests were based. Additionally, limited NPEF testing was conducted on operations using only the lower 10 MHz channel. Our limited testing showed unacceptable interference to all 33 high-performance receivers, as well as certain military receivers, tested in the vicinity of the LightSquared low band transmitter. However, the limited lower 10 MHz channel testing conducted to date does not constitute a sufficient evaluation of LightSquared's revised deployment plan.

A conclusion in the LSQ recommendations paper is that interference "is because legacy GPS receivers do not adequately reject transmissions from base stations operating in the adjacent frequency band because the GPS receivers have been deliberately or, sometimes, inadvertently, designed or manufactured with the assumption that there would be no adjacent-band terrestrial transmissions." In fact, GPS receivers were quite purposefully designed to operate in a portion

of the radio frequency spectrum deliberately maintained as a "quiet neighborhood," with neighboring frequencies primarily occupied by signals of comparable power levels, all based on the widely accepted understanding of previous FCC rules and intent. The proposed LightSquared transmitters will produce received signal strengths five billion times stronger than the GPS received signal.

Some have suggested GPS equipment can be redesigned for greater filtering to mitigate the interference, but even if this is possible, we believe it would involve substantial financial cost and likely degrade the accuracy of high performance receivers, which is critical to many key GPS users. A recent study by the Washington, D.C.-based NDP Consulting Group estimates the costs to GPS commercial users and manufacturers alone at $48.3 billion in research & development and replacement costs if just 50 percent of users required redesign and/or replacement of their equipment. We do not yet have figures for civil or military modifications, but they will be significant, considering the volume of systems to be modified.

Other Considerations

The effects on GPS likely will be shared by our close partners in the Global Navigation Satellite Service community, which include the European Union, Russia, Japan, and China. As these partners build their own space-based navigation systems, we are striving to ensure our systems are as interoperable as possible. If the LightSquared network proceeds, we will need to work with these partners to determine feasible mitigation options. The European Union recently expressed its concerns with the LightSquared plan in a July 19, 2011 letter to the FCC.

Summary

Empirical test results indicate the originally planned LightSquared network does not preserve existing GPS service in representative environments for most users. However, AFSPC remains open to ideas on mitigation strategies that will ensure our continued service to the billions of worldwide users of GPS. We stand ready to work with the NTIA and LightSquared to pursue additional testing on newly proposed deployment plans and receiver filter designs. I thank you again for the opportunity to appear before the Subcommittee and I look forward to your questions.